WRITTEN STATEMENT
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ON

WHAT IS SPACE WEATHER, AND WHO SHOULD FORECAST IT

BEFORE
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Thank you, Mr. Chairman and Members of the Subcommittee, for the opportunity to testify before you regarding the National Oceanic and Atmospheric Administration's (NOAA) activities at the Space Environment Center (SEC). I am Ernest Hildner, Director of the SEC and responsible for day-to-day management and long-term planning of the Center. Space, from the Sun to Earth's upper atmosphere, is a strategic and economic frontier. This unique environment influences a multitude of human activities, and its understanding presents numerous scientific challenges. NOAA's SEC has a central role in conducting and coordinating research to understand the space environment to improve space weather services, and in providing critical operational space weather services for NOAA and the Nation. SEC strives to understand and predict the state of the space environment by accumulating data, running models, applying forecaster insight, conducting applied research, and utilizing research and data obtained externally to make operational forecasts of the space environment. Today I will provide an overview of space weather, of SEC and the services it provides, the budgetary and science challenges facing SEC, how SEC collaborates with other agencies, and the value of space weather forecasting and research. I am pleased to have the chance to discuss these topics today.

SPACE WEATHER

"Space weather" refers to conditions on the sun and in the solar wind, magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems and can endanger human life or health. Adverse conditions in the space environment can cause disruption of satellite operations, communications, navigation, and electric power distribution grids, leading to a variety of socioeconomic losses. **National Space Weather Program Strategic Plan, FCM-P30-1995.**

The Earth lies 150 million kilometers, or 93 million miles, from the Sun, but it is immersed in the extended solar atmosphere. Our magnetic field resists the continual outflow of ionized gas from the Sun, protecting us here at the surface. However, the Earth and its field represent an obstacle to the solar outflow. As a result, the geomagnetic field is compressed on the sunward side of Earth and drawn out away from the Sun to make a comet-shaped cavity. As shown in the artist's sketch below, the size of the boundary between Earth's dominion and the Sun's varies with the pressure exerted by the Sun's outflow.

Space weather storms are spawned by a variety of changes in solar outputs. First, the light from the Sun, at wavelengths both longer and shorter than the visible, can brighten abruptly. This light travels to Earth and affects the near-Earth environment just as we discern that a solar event has occurred. The photons from a solar flare produce a radio blackout, at some frequencies, by changing the character of the dayside ionosphere and upsetting the delicate balance between the Sun's otherwise nearly constant output and Earth's ability to receive and ingest it.

Solar energetic particles comprise a second type of solar emission. These particles, predominantly protons, the nuclei of hydrogen atoms, are accelerated in coronal mass ejections and solar flares. They travel from the Sun slower than the speed of light, arriving near Earth as soon as tens of minutes after the solar eruption, the more energetic particles usually arriving first. The transit from sun to Earth may be slowed if the intervening magnetic fields do not provide easy Sun-to-Earth connection; then the particles' arrival may be delayed many tens of hours. A major rise in energetic particle flux is commonly referred to as a radiation storm.

A third type of solar emission that has strong space weather impacts is magnetized plasma. When the continually evolving solar magnetic fields abruptly restructure themselves over a broad area, a portion of the outer solar atmosphere, the corona, can be ejected violently into space. These coronal mass ejections, clouds of ionized gas (solar plasma) and their embedded magnetic fields, fly away from the Sun at 400 - 1000 kilometers/second (1 - 2 million miles per hour). If Earth happens to be in the way, when

the cloud strikes Earth's magnetic field 2 to 4 days later, then our geomagnetic field is compressed and may be eroded, resulting in a geomagnetic storm.

The following diagram depicts the times scales associated with these three types of space weather events.

The diagram illustrates the lead time between the occurrence of the parent event at the Sun and the terrestrial response; as well as the watches, warnings, and alerts issued by SEC. Thus, space weather has several kinds of storms much as meteorological weather has storms as different as tornadoes, blizzards, and hurricanes. A particular type of space weather storm has significant impacts on particular technologies so some customers are impacted by one type of space weather storm but not by another.

For example, strong x-ray bursts have a serious impact on high frequency (HF) communications on the dayside of Earth. ARINC, a provider of air traffic communications capabilities to commercial airline flights over the North Atlantic, ensures the safety of the movements of airplanes in flight with communications to the cockpit. They need to know when the HF communications are being affected due to natural conditions (space weather) or due to some equipment failure, and advise aircraft of appropriate frequencies to use. The United States Coast Guard is alerted by SEC staff during these same types of episodes as its LORAN navigation system will be unable to provide the required accuracy to its users during solar flare events. LORAN is intentionally made unavailable during these disturbed space weather conditions.

During bursts of solar energetic particles, the second type of space weather storm, the potential for biological damage due to elevated solar radiation increases. The NASA Space Radiation Analysis Group is responsible for assuring that humans in space not receive anything beyond the lowest reasonable radiation dose. They will advise the Flight Surgeon at NASA's Johnson Space Center to alter the activity plan for the crew if those activities involve leaving the space craft (for an extra-vehicular activity, or EVA), or suggest moving the crew to the most highly protected area of the Space Shuttle or International Space Station during the space weather radiation storm. NASA requires forecasts and specifications of radiation that affects both humans and equipment in space.

Another witness will discuss the effects of radiation storms and communications degradation on the airline industry.

Satellites in orbit and during the launch are at risk from radiation storms, and I am pleased to see that you have a witness to discuss those effects of space weather as well.

The third type of space weather storm, caused by the interaction between the onrushing magnetized plasma from the Sun and Earth's own magnetic field, is particularly menacing. This geomagnetic storm can be thought of as the space weather version of a

strong hurricane, as it has very widespread impacts across a large number of systems and users. Somewhat like hurricane clouds are monitored from satellites, this plasma cloud can be seen as it leaves the Sun and it is probed internally as it is about to make "Earthfall".

When a coronal mass ejection occurs, forecasters at SEC analyze the direction of the ejectum to determine whether it is Earthbound and estimate the kinetic energy associated with the event. As it takes a few days for the cloud to reach Earth, there is time for users to take preventive or mitigating action. One of today's witnesses will discuss the effects of geomagnetic storms on the electric power grid.

SEC has been called upon to help investigate possible environmental causes for disasters. The recently active Shuttle Columbia Accident Investigation Board asked for testimony to rule out the possibility that a radiation storm could have affected the Shuttle's computers during reentry. More recently, there were inquiries whether the electrical blackout of the Northeast on August 14, 2003, was caused by a space weather geomagnetic storm. SEC saw no evidence that it was. Ironically, however, as the grid was being brought back up to capacity, on August 18 there was a strong geomagnetic storm that hampered the ability of the operators to return to normalcy.

Another system impacted during geomagnetic storms is the Wide Area Augmentation System (WAAS) of the Federal Aviation Administration, designed for aircraft navigation en route. The WAAS technology relies on the use of the Global Positioning System (GPS), and GPS accuracy is adversely affected during geomagnetic storms. In the current solar cycle, the space weather storm of July 14-15, 2000, was by many measures the most serious. During this storm, the "Test-bed" WAAS was unable to determine the position of a receiver on an airplane to the accuracy required; as a result of the storm, slight changes were made to the WAAS model based on data received during that solar activity.

The Space Weather Operations group at SEC issues alerts, warnings, and watches of space weather storms, on a 24/7 basis. Warnings of all three types of space weather storms are issued when there is high probability of occurrence. Warnings for radiation and magnetic storms are aided by the ability to detect the incoming solar wind from a satellite one million miles upstream, the Advanced Composition Explorer (ACE). This sentinel allows for a few minutes advance notice of radiation storms, and up to one hour lead time for magnetic storms. However, it does not offer any benefit for radio blackouts.

Space weather events such as radio blackouts, radiation storms, and geomagnetic have affected various technologies and systems in sometimes spectacular ways. During the last solar cycle, a geomagnetic storm caused the Hydro-Quebec power grid to black out on March 13, 1989, leaving six million without electricity for nine hours. The big storms of March 1989 and July 2000 sent engineers back to their drawing boards hoping to design better systems to lessen the damage. A space weather radiation storm in August 1972 could have been even more damaging, possibly lethal. This event occurred between the lunar flights of Apollo 16 (April 16, 1972) and Apollo 17 (December 16, 1972). Biologists have calculated that the radiation received by astronauts, had they been on the

moon at the time of the storm, would have caused a quick death. Good luck averted a disaster.

The frequency of occurrence of space weather storms, and the possible consequences of the storms, are indicated in the NOAA Space Weather Scales document attached to this testimony and available on SEC's website at http://www.sec.noaa.gov.

SEC OVERVIEW

What we now call "space weather" began to affect widely used technology during World War II, disrupting the newly developed communication and radar systems. After the War, the Central Radio Propagation Laboratory was set up in the National Bureau of Standards in Boulder, Colorado, coalescing Federal activities dealing with space weather. A portion of this unit, by then named the Environmental and Solar Data Service, was folded into the Environmental Science Services Agency (ESSA) when it was formed in the 1960s. Daily forecasting of the space environment for the public commenced in 1965. ESSA was rolled into NOAA when NOAA was formed in 1970, and the SEC is the result.

NOAA's mission "*To understand and predict changes in the Earth's environment...to meet our Nation' s economic, social, and environmental needs*" includes space weather. Just as NOAA's tropospheric weather service does for its customers, NOAA's space weather service monitors and predicts conditions in the space environment for its customers. SEC carries out its role as the Nation's official source of space weather alerts and warnings under various legislative mandates, statutory authorities, and Department of Commerce Reorganization Plans that gave the authority to monitor and predict the space environment to NOAA. Currently, SEC is both a research laboratory in NOAA's Office of Oceanic and Atmospheric Research (OAR) and one of the National Weather Service's (NWS) National Centers for Environmental Prediction. SEC's products are distributed via email, its Web site, the NWS Family of Services, time and frequency standards radio stations WWV and WWVH, and the NOAA Weather Wire; pager service to notify customers when SEC issues an alert is available from a commercial provider.

SEC is also a member of the International Space Environment Service (ISES), which has 12 Regional Warning Centers around the world to take observations and provide services of regional interest. Daily, the regional centers share their data and tentative predictions with SEC, which synthesizes the information and, as the World Warning Agency, issues the global forecast of space weather conditions. ISES traces its parentage to the International Council of Scientific Unions; its Regional Warning Centers are funded by their host countries.

NOAA's space weather service is analogous to its tropospheric weather service, and both antedate the formation of NOAA itself. Both serve civilian government, public, and industrial users, and both have links to military and academic partners. For both services, NOAA was deemed to be the proper home. Using NOAA's and others' sensors, the SEC continually monitors and daily forecasts Earth's space environment and provides

accurate, reliable, and useful solar-terrestrial information to their customers. SEC acquires, interprets, synthesizes, and disseminates monitoring information to serve the Nation's need to reduce adverse effects of solar-terrestrial disturbances on human activities. It prepares and disseminates forecasts and alerts of conditions in the space environment. SEC conducts research into phenomena affecting the Sun-Earth environment including the emission of electromagnetic radiation and particles from the Sun, the transmission of solar energy to Earth via solar wind, and the interactions between the solar wind and Earth's magnetic field, ionosphere, and atmosphere. It conducts research and development in solar-terrestrial physics and in techniques to improve monitoring and forecasting, prepares high-quality data for national archives, and uses its expertise to advise and educate those affected by variations in the space environment. When events warrant, watches, warnings, and alerts are issued for the use of operators whose systems may be adversely affected by space weather storms. These user groups are private, commercial, government, and military operators, concerned with electric power distribution, high-frequency radio communications, satellite operations, astronaut protection, radio navigation, and national security.

The SEC, however, faces a number of challenges to meeting the needs of the user groups mentioned above. These challenges include budgetary challenges, particularly the potential of cuts in the President’s budget request for SEC in the FY 2004 appropriations bills; and, scientific challenges.

The President requested $8.291 million total for the SEC in FY 2004. However, the House Appropriations Committee has recommended FY04 funding of $5.298 million for SEC, while the Senate Appropriations Committee zeroed out funding for SEC. If the House Committee level of $5.298 is enacted, there will be dramatic consequences for SEC and the vital services that it provides. The House mark of $5.298 million would support staffing of only about 25 FTEs, down from the 53 FTEs requested in the President’s budget. In the short term, most non-labor SEC costs are fixed.

Downsizing to the House Appropriation’s Committee’s recommended level, NOAA and SEC would attempt to preserve, as much as possible, the nation’s investment in the current space weather monitoring network by continuing to acquire, ingest, process, disseminate, and provide to archives the copious data with breaking the continuity of 30 years worth of measurements. This activity currently consumes about half of SEC’s budget. Therefore, the shortfall created by an appropriation of $5.3 million would be borne either by research and development or by operations. NOAA and SEC will be forced to choose between the least undesirable of two options described below. In either case, SEC’s data handling capability for ingest, processing, and archive would degrade. Eighty percent of Air Force alerts are driven by data provided only by SEC. The space weather data ingest and distribution network, identified by Homeland Security as a part of the Nation's Critical Infrastructure, would face imminent failure. For example, under each option, irreplaceable coverage gaps in real-time Solar Wind data would result, as satellite tracking shrinks, reducing alerts of geomagnetic storms affecting communications and GPS accuracy.

In the first reduction option, NOAA would eliminate SEC's research and development while continuing operational services with no improvement. Verification of and technique development to use Solar X-ray Imager (SXI) data would cease. When operational, the SXI takes images of the sun once a minute, providing additional data needed to more accurately forecast and alert users to space weather events. The Global Assimilation of Ionospheric Measurements (GAIM) model currently being developed would not become available to civilian users. This model will provide global specification and forecasts of the ionosphere in 3-dimensions, where presently only in-situ measurements and climatological models are available. NOAA participation in the National Space Weather Program will cease. SEC will not be able to provide improvements to products and models supporting airlines, power companies, navigation, and other critical services. NOAA will be unable to transition into operations the physics based models developed at national centers and universities by NSF, NASA, and DOD-supported scientists. In addition, SEC's website, the primary customer interface for the distribution of space weather data and information will not be improved and recovery from failure will be difficult.

In the second option, NOAA would eliminate SEC 's operational space weather services while continuing research and development against the day that (improved) services can resume. NOAA would cease to issue official U.S. space weather alerts, warnings, and forecasts, information that is currently not provided by any other source. Unfortunately, reducing the current suite of products one-by-one saves very little until the last product is terminated. The infrastructure to support one product supports all, so there is little savings in reducing the number of products. Joint operations with the U.S. Air Force would stop, including providing back-up to the U.S. Air Force's classified space weather support to our armed services. Products supporting airlines, power companies, navigation, and other services and industries would not be prepared, issued, and updated. As noted for research and development, the SEC website would degrade and be prone to complete failure. Real-time operational data systems would be decommissioned.

SEC has several scientific challenges before it. An exciting effort is its work with academic and DOD partners to assimilate data into numerical models, similar to the significant assimilation challenge faced by the meteorological modeling community. The challenge combines computational science and physical understanding of the space environment and will lead to improvements in both. With successful "4-D data assimilation", the model outputs (space weather maps) will be more accurate and more skillful, therefore more useful to users of the services. SEC is working to ensure that space environment monitors designed for GOES and POES satellites provide useful and reliable data on every satellite. Researchers at SEC consult on and write requirements for space weather sensors and, when appropriate, on requirements for the satellites.

SEC has three Divisions; one for services; a second for research and development; and, a third to develop and maintain the computer systems which support the Center's work. The Research and Development Division derives its goals and targets from the needs of the Space Weather Operations Division. In turn, the space weather services products improve from the application of R&D. Having R&D and operational services in one

Center encourages more frequent and more effective interaction and collaboration among the scientists, forecasters, and specialists at SEC. While forecasts, alerts, and warnings are routine for quiet and mildly unsettled solar conditions, when activity becomes intense, forecasters consult with the Center's research Ph.D.s about the forecast. This is because there are not yet good "rules of thumb" for how to deal with these situations, and the best expertise must be brought to bear on aspects of the problem. In addition, the pace of innovation and change is still very rapid in space weather, with researchers at SEC and elsewhere playing a major role in developing models that, if they could be transitioned swiftly into operations, would bring us progressively closer to the goal of physics-based, numerical space weather predictions.

The Research and Development Division is grounded in understanding the fundamental physical processes governing the regime from the solar surface, through the interplanetary medium, into the magnetospheric-ionospheric regions, and ending in Earth's upper atmosphere. These processes determine the climatology and nature of disturbances in the solar atmosphere, in Earth's magnetic field, in the ionosphere, in the charged particle populations at satellite orbits, and in the atmospheric density at high altitudes (including low-Earth orbit). SEC's research, technique development and new sensor implementation are focused on areas where advanced applications can be brought to bear to improve space weather services. The staff has expertise spanning from solar physics to Earth's upper atmosphere and maintains close collaborations throughout the larger research community. They publish regularly in scientific journals, and work directly with the SEC Space Weather Operations and the Systems Division to develop state-of-the-art capabilities for the SEC forecast center. The group develops analysis tools for working with data from a variety of spacecraft, including the NOAA geosynchronous and polar orbiters, and spacecraft in the solar wind. Data access is provided through customized data-analysis routines and individualized displays. In addition to enhancing the utility and value of the primary data through research and analysis, the group explores sources of new data and improved monitoring to support Space Weather Operations. The group leads in the development of techniques to process and interpret both ground-based and space-based solar imagery, and has special expertise in solar X-ray imaging.

The Space Weather Operations Division is the Nation's official source of space weather alerts and warnings. The services center is staffed 24/7 with an operations specialist and, for ten hours a day, a forecaster They continually monitor Earth's space environment with displays and software driven by the approximately 1400 data streams received each day. Forecasters synthesize current data, climatological statistics, and relevant research results to formulate their daily predictions of solar and geophysical activity. Operations specialists ensure data integrity and timeliness; verify event validity and issue Alerts, Watches, and Warnings; and update announcements on the Geophysical Alert Broadcasts over radio station WWV and WWVH.

The Systems Division is responsible for: IT system architecture; computer security; developing or acquiring, and maintaining, the computer hardware and software to routinely ingest data; populating the data bases; the hardware and software for

disseminating data and products to customers and to the archive; and providing computer configuration control and redundancy for operational reliability. In addition, Systems Division personnel provide system administration and support to internal users, while responding to IT directives from the NOAA and OAR Chief Information Officers, and working with administrators of the several local Internet services. The Division operates the receiving antennas at the prime and back-up Boulder sites, and has personnel on-call at all times to attend to hardware and software failures which affect the functions of the forecast center.

SEC performs a vital role for the nation in conducting and coordinating research and its application. The recent National Research Council report - A Decadal Research Strategy in Solar and Space Physics (2003), recommended that NOAA should assume full responsibility for space-based solar wind measurements, expand its facilities for integrating data into space weather models, and, with NASA, should plan to transition research instrumentation into operations. As discussed in the National Space Weather Program Implementation Plan (2000), interagency programs cannot succeed in meeting the Nation's needs without NOAA SEC observations, research, model development, and transition to operations. And, as emphasized in the Department of Defense's (DOD) National Security Space Architect Study (2000), NOAA' s current and planned activities are essential to meet DOD's space weather needs.

In addition to the SEC's activities, it should be noted that three line organizations play roles in the NOAA Space Weather Program: National Environmental Satellite, Data, and Information Service (NESDIS), National Weather Service (NWS), and Office of Oceanic and Atmospheric Research (OAR), with some interest and support from the National Ocean Service. They cover the gamut of space weather activities from setting requirements for future space environment monitoring sensors and spacecraft, to monitoring the development of the sensors for flight on the Geostationary Operational Environmental Satellites (GOES) or Polar Operational Environmental Satellites (POES), to tracking and downloading data from NOAA and non-NOAA satellites, to processing and distributing the data, and finally to archiving the data. Many of these activities are contained within and are an integral part of NOAA 's major programs, such as the GOES and POES programs, so that only the Space Environment Center (OAR) and part of the National Geophysical Data Center (NGDC) in NESDIS are clearly identified budget structures tied directly to NOAA's space weather program. The requirements process also identifies observations needed in addition to the GOES and POES programs and programmatic plans are made for these platforms as well. NGDC is the sole archive of routine monitoring data of the space environment recorded on GOES, on POES, and on DOD's Defense Meteorological Satellite Program satellites. It is also the sole archive of space environment monitoring data recorded at DOD ground-based solar and ionospheric stations. As noted below, NOAA also works closely with other federal agencies and nations to obtain available real-time space weather data enabling more accurate and timely space weather services for the nation.

COLLABORATION WITH PARTNERS

SEC works with a variety of partners to accomplish its mission. Internally, cooperative ventures abound as graduate students, post-doctoral students, visiting scientists, Cooperative Institute fellows from the University of Colorado, and contractors all contribute to the effort at the Center. Additionally, SEC works with the Cooperative Institute for Research in Environmental Sciences, a NOAA Joint Institute.

SEC works closely with colleagues across government agencies and academia, in the U.S. and internationally, to understand the space environment and apply research results. Collaboration requires a great deal of coordination within the U.S. and internationally. Within the U.S. Government, the Office of the Federal Coordinator for Meteorology provides a mechanism for space weather coordination, including development and implementation of the National Space Weather Program (NWSP). The National Aeronautics and Space Administration (NASA), the National Science Foundation (NSF), and the Departments of Defense (DOD), Interior (DOI), Energy (DOE), Commerce (DOC), and Transportation (DOT) are participants in the NWSP, which recognizes common interests in space weather observing and forecasting. Aware of the need for prudent employment of available resources and the avoidance of duplication in providing these services and support for agency mission responsibilities, the cooperating departments have sought to satisfy the need for a common service and research program under the NWSP. The NWSP's Implementation Plan sets out the expected data, research, and services contribution from each participating agency.

To provide its specification and forecast services, SEC works most closely with the U.S. Air Force Weather Agency's forecast center in Omaha, which provides services to U.S. military customers. NOAA civilians and uniformed NOAA Corps and U.S. Air Force personnel together staff the joint services center in Boulder. NOAA and USAF share their data without charge to each other, and confer every day before the daily forecasts are issued by the two agencies to their respective clients. The SEC provides centralized space weather support to non-DOD government users, such as NASA, and to the general public, such as the commercial airline industry. SEC operates and maintains a national real-time space weather database to accept and integrate observational data, to provide operational support and services in the space and geophysical environment, to provide services to public users in support of the national economy, and to serve as the U.S. Government focal point for international data exchange programs. The USAF provides unique and classified support to all DOD users. The Space Weather Operations Center (SPACEWOC) at the Air Force Weather Agency (AFWA) serves as the DOD focal point for space weather forecasting support and services. The USAF maintains a worldwide network of both ground-based and space-based observing networks to provide accurate, reliable, and timely support to military communications, surveillance, and warning systems. To avoid duplication, the two agencies share responsibilities to produce certain space weather databases, warning, and forecast products of mutual interest and benefit to each other. AFWA and SEC provide cooperative support and backup for each other in accordance with existing agreements.

NOAA procures, operates, and maintains the Space Environment Laboratory Data Acquisition System (SELDADS) as the national system for collection, integration, and

distribution of solar-geophysical data received in real-time from ground-based observatories and satellite sensors. Collection, processing, monitoring, and storage of the data occurs continuously around the clock. Displays and interactive analyses of the data are used by SEC to provide alerts, forecasts, and data summaries to a user community consisting of industrial and research organizations and Government agencies in the United States and abroad.

The collaboration among space weather service providers and those who fund their research is closely coordinated and mutually beneficial. NASA and DOD conduct critical research and development activities that NOAA assesses and incorporates, as needed, onto its civil operations spacecraft. NASA's upcoming Living with a Star set of missions and their accompanying data and research are oriented toward improving space weather monitoring and improving techniques for understanding space weather effects and the inference of the physical processes that shape the space weather environment. These are important because they enable the production of new physical models for improved predictability of the space weather environment and its evolution. The space industry also provides expertise to assist in various projects. Increasingly, collaborations with the private sector and foreign remote sensing operators provide data and information that NOAA and other government agencies such as the USDA, DOE, and DOI use to implement their respective missions.

SEC also works actively with partners in industry and other users on specific projects to identify research and forecast needs. For example, SEC has one active Cooperative Research and Development Agreement with Federal Data Corporation (FDC) to develop a model of the wavelength-dependent changing solar brightness for customers interested in ionospheric changes and heating of the terrestrial atmosphere. NASA's Marshall Space Flight Center (MSFC) and SEC scientists, with others, issue and update the world consensus forecasts of the 11-year cycle of solar activity for the benefit of NOAA, NASA, DOD, and others; this is the forecast used by NOAA, NASA, DOD, and the international community for mission planning. Spaceweather.com, a Web site fostered and supported by MSFC, makes heavy use of SEC's data and products. The website exhibits data gathered from SEC. SEC is first in the site's list of "essential" links.

SEC also co-sponsors Space Weather Week annually with other government agencies such as the Air Force Research Laboratory, NSF Division of Atmospheric Science, and NASA Sun-Earth Connection Program. This event brings hundreds of users, researchers, vendors, government agencies, and industry representatives together in a lively dialog about space weather. Discussion focuses on recent solar and geomagnetic activity, specific space weather impacts, and our scientific understanding of this activity. The conference program highlights space weather impacts in several areas of the environment including ionospheric disturbances, satellite drag, auroral currents, geomagnetic storms and their solar drivers, radiation belts, and solar energetic particles. The conference registration fee covers almost the entire cost of the conference. The rest of the conference expenses are covered by NSF, specifically some costs for invited speakers, students, special guests and support for international partners to attend. SEC, the DOD Air Force Research Lab and NASA all assist with the planning of Space Weather Week, and

representatives from industries impacted by space weather including those from electric power, commercial airlines, satellite operations, and navigation/communications are among frequent participants and contributors. The attached spreadsheet highlights comments SEC has received from users about impacts of space weather on their efforts.

VALUE OF SPACE WEATHER FORECASTING AND RESEARCH

In the last few years, there has been a large increase in society's need for space weather information, as geomagnetic storms and solar disturbances can impact a wide array of sectors and industries ranging from transportation to electricity generation. SEC's website receives on average more than 500,000 hits per day from commercial and public users. This number can triple during severe space weather events. SEC forecasts and research helps support a wide array of needs including the U.S. power grid infrastructure, commercial airline industry, Global Positioning System or GPS, NASA human space flight activities, satellite launch and operations, and U.S. Air Force operational activities.

The direct global economic impact of space weather has been estimated at about $200 million per year. A 1 percent gain in continuity and availability of GPS information, which can be disrupted by space weather events, would be worth $180 million per year. DOD alone spends $500 million each year to mitigate space weather effects. In 1989, a space weather storm caused such significant orbital decays that the Air Force Space Command lost track of 1,300 of the 8,000 objects orbiting in space that it was tracking. In addition to the potential harm radiation from a space weather event can cause astronauts and sensitive electrical equipment in space, these rapid changes in flight paths of space debris could be potentially harmful should they intersect with the paths of astronauts or satellites in space. In March 1989, seven geostationary satellites had to make 177 orbital adjustments in two days, more than normally made in a year. Such wear reduces the satellites' useful lifespan. Destruction of AT&T's Telestar satellite by a severe weather event in 1997 disrupted TV networks and part of the U.S. earthquake monitoring network, and forced renegotiation of the sale of Telestar, resulting in a drop of $234 million in value. Submarine, continental cables, and parts of fiber optic cable systems have all been known to fail or be overloaded as a result of space weather.

Geomagnetically-induced currents can disrupt or wipe out electrical systems through power surges that cause network supply disruptions, transformer damage, and wear-and-tear on other components. As we apparently witnessed this summer during the blackout in the north, a single failure in the power grid can escalate into cascading damages and outages. Oak Ridge National Laboratory estimates that a blackout in the Northeast caused by geomagnetic storms could result in a $3-6 billion loss in Gross Domestic Product (GDP). A geomagnetic storm in 1989 caused $13.2 million in damage to power systems operators in Quebec, and another $27 million to power operators in New Jersey. In addition, the disruption creates additional impacts for power customers who lose electricity. After 1989, Hydro-Quebec spent $1.2 billion on capacitors to prevent potential space weather disruptions. A current, induced by severe space weather, in a liquified gas pipeline that ignited when two trains passed over it is the suspected cause of an accident that killed over 500. Preventative measures, based on early forecasts

from the SEC and its partners, can help mitigate the need for such costly alternatives as shielding power lines. One recent estimate suggested that the use of good forecasts by the power industry could save the U.S. $365 million per year, averaged over the solar cycle

Not only do we depend more heavily on systems that can be adversely impacted by space weather, new systems and new modes of operation using old systems vulnerable to space weather have proliferated. Satellites are becoming smaller and cheaper because of reduced component size and increased computer speeds. Economic competition drives the need to reduce shielding and redundancy, but these changes leave satellites more vulnerable to space weather disturbances. U.S. airlines are offering passengers the convenience of non-stop flights over the North Pole to Asian destinations; these flights (and research flights in Antarctica) sometimes experience air traffic control difficulties due to space weather. During a March 2001 space weather storm, 25 flights were rerouted to avoid the Poles because of the increased radiation risk.

National policy and defense planning have resulted in increased reliance on the use of commercial systems to gather information and move it between the United States and troops and ships in hot spots around the world. However, experiences during severe conditions of the last solar cycle indicates that some users may experience performance failures and degraded results during times of high solar and ionospheric activity. The nation is also placing large numbers of astronauts into radiation-vulnerable orbits for unprecedented periods of time during the assembly and operation of the International Space Station. Our increased need for improved space weather information to insure safety, reliability, and defense are inevitable outcomes of our growing use of space-weather-sensitive systems.

SEC has been keeping up with the changes, responding to new customer needs, research breakthroughs, and the changing face of space weather services. Among several successes, it has transitioned physics-based numerical models into the operational space weather service. It was possible to use the first of these university-developed models only when real-time solar wind data from upstream of Earth became available to drive them. Now forecasters get numerical guidance, much as meteorological forecasters do. Model output can be disseminated to provide customers with the space weather analogs of meteorological weather maps, showing event locations and intensities of computed fronts and boundaries. SEC has designed website to make it user-friendly for a range of audiences, from electricity producers to teachers and the media.

A solar x-ray imager on GOES-12 was made operational in 2003, funded as a USAF-NASA-NOAA partnership, and has provided images of the solar corona at a rate of once per minute. Images are able to show visible coronal changes that signal events on the Sun which will later cause space weather storms. This imager is the first of its kind, and it shows more capability in imaging the Sun for forecasting purposes than any solar imager to date. Automating the extraction of information from these images and incorporating the information into specification and forecast algorithms is already shedding light into the causes of solar wind and eruption events hazarding Earth.

However, on the morning of September 2, 2003, the GOES-12 SXI instrument automatically transferred into an instrument safe (non-operational) mode. Two attempts were made to raise instrument voltages to their normal operating levels, but both attempts failed. Development of plans to return the SXI to limited operations is underway.

SEC is also active in developing products and services for the next generation air transport system. Working with both the commercial airlines and the FAA, SEC is formulating new products to serve airline operations of the future. That future is certain to include higher flying and trans-polar air routes as each allows for a faster more profitable trip. Particular issues that are impacted by space weather are navigation, radio communication, and radiation to the passengers and crew. Recent work with the FAA's User Needs Analysis Team (UNAT) has led to the implementation of SEC alerts and warnings into the operational planning for commercial airlines on trans-polar routes. Specifically, communications from air to ground, and the management of the radiation environment are points of concerns for the FAA. SEC has worked to supply the appropriate real-time information to be used by aircraft dispatchers.

CONCLUSION

In conclusion, Mr. Chairman and members of the Subcommittee, NOAA is pleased to have had the opportunity to provide you an overview of space weather and SEC, our collaborative activities with our partners, and the value of space weather forecasting and research. We look forward to continuing our efforts to provide a critical service for our Nation by providing cutting-edge research and forecasts in the space weather arena. I would be happy to answer any questions you may have.